SCIENCE

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THE VALUE OF RESEARCH TO INDUSTRY[1]

THE large chemical industries and, in fact, all branches of chemical technology have been immensely developed during the nineteenth and twentieth centuries, and the achievements of chemistry in the arts and industries have been stupendous and varied. In particular, industrial research —definable as "the catalysis of raw materials by brains"—has been and is being increasingly fostered by chemical manufacturers, and this has led to the accruement of important novelties and improvements.

Many excellent résumés of the development of industrial chemistry during the modern chemical period have appeared in the literature. I shall only remind you that these indicate how industrial chemistry has been elevated by a continuous infusion of scientific spirit, and that manufacturing, once entirely a matter of empirical judgment and individual skill, is more and more becoming a system of scientific processes. Quantitative measurements are replacing guesswork, and thus waste is diminished and economy of production insured. In the United States, several decades ago, few industrial establishments furnished regular employment to chemists, but now American manufacturers are becoming more and more appreciative of scientific research, and the results so far obtained have resulted in far-reaching improvements. In the production of a metal from its ores, or of benzene derivatives from coal-tar, it is chemistry that points

[1] An address delivered, by invitation, at the inaugural meeting of the session of the Royal Canadian Institute, Toronto, November 7, 1914.

the way, and the more complex the problem the greater the dependence. In devising new processes and in the discovery of new and useful products, chemistry is again the pathfinder. The community is apt to overlook the extent and diversity of the services rendered by the chemist, because of the quiet and unobtrusive way in which the work is carried out.

The measure of a country's appreciation of the value of chemistry in its material development and the extent to which it utilizes this science in its industries, generally measure quite accurately the industrial progress and prosperity of that country. In no other country in the world has the value of chemistry to industry been so thoroughly understood and appreciated as in Germany, and in no other country of similar size and natural endowment have such remarkable advances in industrial development been recorded, and this, too, with steadily increasing economy in the utilization of the natural resources.

THE CHEMICAL INDUSTRIES OF GERMANY

The history of the great firm of Farbwerke vorm. Meister Lucius und Brüning at Höchst a/M., Germany, serves as an admirably typical record of the development of German chemical industry.

In 1862, two chemists and two merchants organized a firm for the manufacture of tar colors, and the plant was started the following year with five workmen, one clerk, and one chemist. One boiler of 3-horse-power supplied the power. Fuchsin, anilin blue, alkali blue, aldehyde green, methyl violet, methyl green and malachite green were the first products. In 1869, the manufacture of alizarine was taken up. In 1878, new buildings were erected for the manufacture of azo-dyes, and two years later the firm was formed into an Actien-Gesellschaft. In 1883, the manufacture of pharmaceutical preparations were started with antipyrine; in 1892, Koch's tuberculin and Behring's diphtheria serum were prepared and marketed; and in 1898 the manufacture of synthetic indigo was begun. The number of types and colors manufactured twenty-five years ago amounted to 1,750; in 1913, about 11,000 were manufactured. In 1888, the steam engines had a total horse-power of 1840; in 1913, 30,000 horse-power were required. In 1888, 1,860 workmen and *57 chemists* were employed; in 1912, 7,680 workmen, 374 foremen, *307 chemists* and 74 other technical men were on the payroll. In 1912, 8.6 million marks were paid in wages and 5.2 million marks in salaries and bonuses.

Since Wallach began his investigation of essential oils and terpenes in 1884, the manufacture of perfumes in Germany has grown continuously. In 1895, synthetic neroli oil was prepared; in 1896, oils of jasmine and hyacinth blossoms, and, in 1908, the essential oils of lily of the valley, were synthesized. In the explosives industry the chief efforts have been directed to the manufacture of safe products. While in 1890, 4,938 tons of dynamite were produced and only an insignificant quantity of safety explosives, in 1909 the production of safety explosives amounted to 10,000 tons as compared with 8,000 tons of dynamite. The great development of the German dyestuffs industry led to developments in many other branches, especially in the sulphuric acid, chlorine, tar-oils and nitric-acid industries. The development of the cyanide process for the extraction of gold also led to the introduction of a new technical process of manufacturing synthetic indigo, based on the use of sodium amide in the alkali fusion of phenylglycin. In 1913, the selling value of the synthetic indigo on the world market amounted to

nearly $2,500,000. The demand of the dyestuffs works for coal-tar products also led to the great development in the recovery of by-products in coke manufacture. The recovery of ammonia as ammonium sulphate, a valuable fertilizing material, has grown rapidly in Germany.

The purely inorganic chemical works in Germany have been in a different position as compared with the large color works, which, with their large and excellent scientific and commercial organization, as well as their splendid financial position, represent enormous powers. The German color works long ago ceased to purchase the inorganic products they required. In 1913, they worked their own mines, made all inorganic and intermediate products themselves, not only for their own requirements, but also for sale, and controlled every branch of chemical industry. The great advance of these large concerns made it very difficult for the inorganic works to take up new manufactures to compensate for the continued falling-off in the profits on heavy chemicals.

Much is to be learned from a study of the history of German technology. We find, for instance, that the progress of industrial chemistry, especially in its synthetic branches, has lagged in the United States because the United States corporation and patent laws are unfavorable (in Germany a patent must be worked or forfeited) and because there is no large supply of cheap researchers. German conditions in these respects have been the direct causes for the German development. However, with proper legislation, the chemical industry will develop in the United States, at least to the same extent as in Germany, for American engineering ingenuity will serve to counterbalance the advantage of cheap labor; and the same applies to Canada, whose engineers have demonstrated skill and resource in many developments of importance to the Dominion.

Like Canada, the United States has unnecessarily imported too much. Given proper conditions, American industrialists can take care of a large amount of goods now being imported, and in some cases produce them here. In other cases, they could even become exporters of commodities now imported. To accomplish this, however, a large amount of research will be necessary, and, in general, considerable investments will have to be made.

THE CHEMICAL INDUSTRIES OF SWEDEN

Since most of the rivers of Canada possess waterfalls on their course, they must become increasingly important as sources of power, the basis of industry. Your swift-flowing streams, capable of supplying almost unlimited power, remind one of those which are the boast of Sweden and Norway; and like these countries, Canada has not only waterfalls, but she has many lakes, which will serve some day as large natural reservoirs for conducting the water to the power stations. It is appropriate, therefore, that brief reference be made to the chemical industries of Scandinavia.

Sweden is a land in which chemistry has played an important rôle from an early date. No less than twenty of the known chemical elements have been discovered by Swedes, and we are all familiar with the pioneer work of Scheele and Berzelius during the constructive period of chemistry.

Sweden owes to three factors its past and present position in industrial chemistry: an abundantly diversified mineral wealth; forests of enormous extent; and abundant water power. Its metal products are of notably high quality; the manufacture of cellulose in its varied forms constitutes an enormous industry; and the electrochemical industries have availed themselves of

the vast water power. Research is constantly in progress, and the results of the Swedish investigations in the electric smelting of iron ores have indicated much for a better utilization of the iron deposits in certain parts of the United States where conditions are not unlike those existing in Sweden.

THE CHEMICAL INDUSTRIES OF NORWAY

There are several features worthy of careful study in connection with the chemical industries of Norway. First is the very systematic and exhaustive manner in which the abundant water power of the country has been regulated, stored up, and pressed into the service of the constantly growing group of electrochemical industries. The highest engineering and chemical talent of Norway is patriotically enlisted in this cause, and already the road is constructed for little Norway to assume an industrial position commensurate with its geographical size and maritime facilities.

In the field of industrial organic chemistry, Norway has also shown her ability to develop an industry—the manufacture of oxalic acid. This is a branch of manufacture which has never been developed in North America, and, as there is only one plant producing oxalic acid in the United States, comparatively enormous amounts of money have normally been expended annually in the purchase of this commodity in Norway and Germany.

While the climate is severe, coal is lacking, the mineral deposits are not easily accessible, and the conditions of life are comparatively hard, the Norwegians have brought certain chemical industries to the fore. In the development of these, chemical research has had a prominent part.

THE CHEMICAL INDUSTRIES OF HOLLAND

The Netherlands offers a most interesting example of what can be accomplished in building up diversified branches of the chemical industries when there is an almost complete dependence upon foreign fuel and raw material. The evolution of the manufacture of starch, of mineral pigments, of matches, and fertilizers, as well as the industries connected with the oils and fats, are most instructive in this connection.

Providing the people of Holland remain free from military burdens, it may be predicted that the exceptionally high degree of thrift, intelligence and enterprise characterizing the Dutch will enable them to accomplish the enlargement of the field of chemical industry and to free the country from dependence upon foreign sources of supply of finished products.

THE CHEMICAL INDUSTRIES OF BELGIUM

Prior to the present war, Belgium was regarded from the standpoint of the technologist as offering a most instructive example of what can be done in a small country in the healthy development of a large group of closely allied industries. All the chemical branches dependent to a greater or less extent upon the natural products of the land had been brought to a high state of perfection. In addition, numerous chemical industries utilizing raw materials of foreign origin had been called into existence. Then, too, the ability to capture, in various directions, foreign markets for different chemical products had been revealed to an astonishing degree.

The Belgian chemists of the next decade will once more be obliged to concentrate their endeavors in building up the industries for which the little kingdom was so worthily famous—the production of staple articles of value. In this line they will, no doubt, show that high degree of inventive skill, capacity for organization and commercial acuteness which has always characterized the Belgian technologist.

THE INDUSTRIAL CHEMISTRY OF TO-DAY

The picture that technical chemistry presents to-day is quite different from that of thirty years ago. There is more brilliancy around the accomplishment of the organic than of the inorganic industries. The replacement of natural dyes by the products of coal tar, the extension of our medical resources by the manufacture of synthetic medicines, has gone far to extend the appreciation of chemical work and to produce the general conviction that chemistry is an inexhaustible field of economic possibilities. Indeed, one natural product after another falls into the domain of chemical synthesis, and chemistry is becoming the important factor in the economy of the tropical products which are used for industrial purposes. As soon as the price of such a product exceeds a certain limit, organic chemistry enters the field and synthesizes it. Tanning materials are in a struggle with the condensation products of formaldehyde and phenolsulfonic acids. Camphor could maintain its position only by large price reduction, and the prospect of synthetic rubber has held down the would-be inflated prices of the natural product. The basis of this marked development in organic chemical industries is the combined working of science and technology. The success of this intermingling is so obvious that I need not dwell on the point.

In the domain of inorganic technical chemistry things are somewhat different. Here, too, a great change has taken place. The historical sulphuric acid and soda processes have lost much ground to the ammonia-soda and electrolytic processes, and to the contact process. New branches of industries have taken root and grown up. In this field, however, the connection between scientific and technical progress is neither so obvious nor so well recognized as in the realm of industrial organic chemistry. The reason is that the advance in inorganic science, during the last decade or two, has resulted less in the discovery of new facts which had direct technical applications, than in the elucidation and working out of new theoretical views. In fact, the introduction of physical laws and physical methods into the working sphere of inorganic chemistry has led to the greatest scientific progress. The invasion of physics into chemistry has produced the splendid development of physical chemistry, the basis of which is the second law of thermodynamics, the phase rule, and the theory of electrolytic dissociation. The introduction of the electroscope into chemical analysis has opened up the new chemical world of radioactivity. Now inorganic chemical industries can gain almost as much by regarding their problems from a physical point of view as organic industries do by the application of structural considerations.

THE VALUE OF PHYSICO-CHEMICAL RESEARCH

Owing to the progress of physical chemistry, based largely upon thermodynamics and including the accurate quantitative study of the conditions determining the reactivity of substances and the velocity of chemical change, chemistry has, indeed, undergone revolutionizing changes during the past twenty-five years. The study of the behavior of catalysis comes well within the province of physical chemistry. As examples of industrial processes based upon catalytic action, I shall mention in passing the Deacon chlorine process, the contact sulphuric process, the hydrogenation of unsaturated fatty acids and their esters, the synthesis of ammonia from its elements, the oxidation of naphthalene in the production of synthetic indigo, and certain methods of surface combustion.

Fermentation industries and the whole field of agriculture depend upon physical chemistry for their further progress and development; for enzymes are essentially

catalysts and the stimulating action of small quantities of inorganic compounds on the growth of plants has been demonstrated. For instance, very small additions of manganese or zinc, or mixtures thereof, increase the yield of plant culture.

In this connection I may refer to the application of the phase rule by van't Hoff to the better utilization of the Strassfurt salt deposits, and to electrochemistry, photochemistry, and to the chemistry of colloids.

The successful solution of the problem of the oxidation of atmospheric nitrogen, the production of ammonia from its elements, and the manufacture of sulphuric acid by the contact process, were only made possible by the knowledge of the principles and methods of chemical dynamics and thermodynamics.

Further, the teachings of physical chemistry have led to the study of the conditions of absorption of drugs by the various cells and tissue juices of the body, of the part played therein by osmosis, by electrolytic dissociation, by mass, and especially by the colloidal character of the substances concerned in metabolism. Such study associated with biological chemistry has pointed the way to new methods of research which promise well for a fuller understanding of the complexities of the processes that are comprised in the physiological action for drugs.

Despite the mass of material that has thus been accumulated, a scientific basis for the preparation of physiologically active compounds is but in its infancy. The possibility of precalculating the action of a drug from its chemical structure is as yet developed to but a limited extent, as has been repeatedly brought home during recent years by the discovery of new groups of compounds possessing valuable therapeutic properties, the physiological action of which was in no way anticipated. Indeed, the recognition of the therapeutic value of some of the earlier synthetic drugs was effected, as Keane has indicated, rather in accord with Priestley's belief that all discoveries are made by chance, and has been extended with some reminiscence of his view that scientific investigation was to be "compared to a hound, wildly running after and here and there chancing on game." The hypnotic property of sulphonal was a chance discovery; the physiological action of antipyrine was initially examined on account of its supposed relation in chemical structure to kairine and allied febrifuges, which was subsequently proved to be incorrect; and the purgative properties of phenolphthalein became known from the results that followed its use to earmark, for administrative purposes, a certain kind of wine in Austria-Hungary. The commercial success of antipyrine—the profits in one year from its manufacture before the expiration of the patent are said to have reached $300,000—was followed by a hunt for further "game" and many a compound, such as acetanilide, has been called from the seclusion of chemical museums for the examination of its physiological properties.

The recognition of the therapeutic value of such substances has been followed by inquiry into the relation of their chemical structure and physiological action, with the result that the study of this relation has since become more ordered and systematic.

GEOCHEMICAL RESEARCH

A study of the manner in which certain minerals are usually found associated together in nature, commonly those which are isomorphous or which contain the same group of elements, but very often of entirely different mineralized and chemical character, is of particular importance to the commercial man, and should be of great

assistance to those chemists and physicists who study the genesis of minerals and "elements" and the so-called degradation of the latter. Just as the periodic law of Newlands and Mendeléeff was evolved from the tabular collating of chemical and physical data, and was found capable of prophetic use, so one may learn and predict much from a study of the known associations of minerals, and particularly those of the rare metals. One has the advantage of knowing that minerals have been produced under natural conditions where no mistakes or errors of manipulation can have occurred and where no difficulties due to want of time, material, or facilities for experimenting existed; in other words, where the personal factor was absolutely non-existent.

Probably the most promising field for research exists in the oldest plutonic rocks, and particularly in such pegmatites and other extremely old granitic and other rocks as have been subjugated, at great depth and pressure and at high temperatures, to the action of intruded flows of fused mineral matter from still deeper-seated sources, or of vaporized mineral matter of similar origin. Such rocks exist in many parts of the world, but the pegmatites of Norway, the old granites of Greenland, and many of the old but less highly crystalline tin-bearing deposits of Cornwall, may be instanced as likely to throw light on the origin of certain metals, and especially of those at the "heavy" and "light" ends of the periodic table. Perhaps

> There is in this business more than nature
> Was ever conduct of.

It is probable that some of the missing heavy elements near the uranium end of the table may be found in such rocks, and that certain light elements, for which room may have to be made in the table, may also be discovered.

The comprehensive investigations in progress at the geophysical laboratory of the Carnegie Institution illustrate the change now occurring in geochemical research.

THE VALUE OF RESEARCH IN METALLURGY

To the valuable properties of the many alloys of iron now manufactured, from carbon steel to the complex alloy known as high-speed tool steel, which contains no less than five different elements apart from the iron itself, is to be attributed the great progress which has been made, whether in the arts of peace or in war. There is one simple concrete instance—the modern automobile. Eliminate the alloy steels used in its construction, and it could no longer be produced. The combination of lightness and strength necessary in such modern products is only made possible by the use of special alloy steels.

While the progress made in alloy steels since Hadfield's first researches in 1882 and onwards has been wonderful, indeed, the field for research is still an immense one, full of difficulties, disputed points, and important problems. It is true that there may not be at the present time room for such abnormal discoveries in ferrous metallurgy as in the past, but investigators are quietly and steadily augmenting our knowledge of iron and its alloys, and the value of such research work is generally recognized.

It remains to mention in this connection that the science of metallography, which has so materially aided the progress of metallurgy, has been developed by the assistance of the phase rule.

Research work of an elaborate nature is constantly being conducted by several manufacturers, especially at Homestead, Pa., by the United States Steel Corporation, which has to date expended over $800,000 in investigations on the electro-

thermic production of steel alone. However, metallurgical research laboratories are still comparatively uncommon. Very few iron furnaces or smelting plants are without a control laboratory, which has come about notwithstanding the opposition of "practical men," and the research laboratory will eventually win a similar victory.

The great problems at present in the metallurgy of zinc are in the concentration of the ore and in the treatment of flotation concentrate. The latter produces the troubles that fine ore always does; it is difficult to roast, and the distillation of it is attended with troubles.

Viewing the present status of the practise in zinc smelting, one is impressed by the high extraction results, the low fuel consumption made possible by regenerative gas-firing, and the reduction of labor involved in the art.

In copper metallurgy, the leaching of copper ores and electrolytic deposition for precipitating are receiving increased attention. In electrolytic copper refining, promising progress has been made in the treatment of anode slimes; and more attention is being paid to the recovery of by-products, new uses for two of which, selenium and tellurium, are required.

COOPERATION BETWEEN SCIENCE AND INDUSTRY

While those engaged in a profession which has so many ramifications as has chemistry in its numerously various applications to all modern activities, must cooperate to effect advancement, before such cooperation can be effective, there must be a mutual understanding between chemists as a profession and industrialists. Many American chemical manufacturers still follow rule-of-thumb methods without having any idea of the underlying principles which are immutable. These manufacturers must be induced to recognize the actuality of such principles and to realize fully that an actual comprehension thereof is necessary for the attainment of that measure of success necessary to maintain uniform quality and maximum output of product.

In this connection, I may say that the system of practical cooperation between industry and learning, founded by the late Dr. Robert Kennedy Duncan, has had eight years of trial. The outcome of my eminent predecessor's labors, The Mellon Institute, through its industrial fellowship system, represents a happy and successful alliance between science and industry, for a valuable and permanent relation has been established by the solution, at the institute, of many important manufacturing problems.

THE METHODS OF ATTACKING INDUSTRIAL PROBLEMS

When a chemical industry has problems requiring solution, these problems can be attacked either inside or outside of the plant. If the policy of the management is that all chemical problems are to be investigated only within the establishment, a research laboratory or at least a research chemist must be provided for the plant or for the company. At present, in the United States, probably not more than 100 manufacturing establishments have research laboratories or employ research chemists, although at least five companies are spending over $100,000 per year in research. In Germany, and perhaps also in England, such research laboratories in connection with chemical industries have been much more common. The great laboratories of the Badische Anilin und Soda Fabrik and of the Elberfeld Company are striking examples of the importance attached to such research work in Germany, and it would

be difficult to adduce any stronger argument in support of its value than the marvelous achievements of these great firms.

An unfortunately frequent difficulty encountered in the employment of research chemists, or in the establishment of a research laboratory, is that many manufacturers do not appear to grasp the need or importance of such work, or know how to treat the men in charge so as to secure the best results. The industrialist may not even fully understand just what is the cause of his manufacturing losses or to whom to turn for aid. If he eventually engages a chemist, he is sometimes likely to regard him as a sort of master of mysteries who should be able to accomplish wonders, and, if he can not see definite results in the course of a few months, is occasionally apt to consider the investment a bad one and to regard chemists, as a class, as a useless lot. It has not been unusual for the chemist to be told to remain in his laboratory, and not to go in or about the works, and he must also face the natural opposition of workmen to any innovations, and reckon with the jealousies of foremen and of various officials.

From the standpoint of the manufacturer, one decided advantage of the policy of having all problems worked out within the plant is that the results secured are not divulged, but are stored away in the laboratory archives and become part of the assets and working capital of the corporation which has paid for them; and it is usually not until patent applications are filed that this knowledge, generally only partially and imperfectly, becomes publicly known. When it is not deemed necessary to take out patents, such knowledge is often permanently buried.

In this matter of the dissemination of knowledge concerning chemical practise, it must be evident to all that there is but little cooperation between the manufacturers and the universities. Chemical manufacturers have been quite naturally opposed to publishing any discoveries made in their plants, since "knowledge is power" in manufacturing as elsewhere, and new knowledge gained in the laboratories of the company may often very properly be regarded as among the most valuable assets of the concern. The universities and the scientific societies, on the other hand, exist for the diffusion of knowledge, and from their standpoint the great disadvantage of the above policy is this concealment of knowledge, for it results in a serious retardation of the general growth and development of the science in its broader aspects, and renders it much more difficult for the universities to train men properly for such industries, since all text-books and general knowledge available would in all probability be far behind the actual manufacturing practise. Fortunately, the policy of industrial secrecy is becoming more generally regarded in the light of reason, and there is a growing inclination among manufacturers to disclose the details of investigations, which, according to tradition, would be carefully guarded. These manufacturers appreciate the facts that public interest in chemical achievements is stimulating to further fruitful research, that helpful suggestions and information may come from other investigators upon the publication of any results, and that the exchange of knowledge prevents many costly repetitions.

INDUSTRIAL FELLOWSHIPS

If the manufacturer elects to refer his problem to the university or technical school, such reference may take the form of an industrial fellowship and much has been and may be said in favor of these fellowships. They allow the donor to keep secret for three years the results secured, after

which they may be published. They also secure to him patent rights. They give highly specialized training to properly qualified men, and often secure for them permanent positions and shares in the profits of their discoveries. It should be obvious at the outset that a fellowship of this character can be successful only when there are close confidential relations obtaining between the manufacturer and the officer in charge of the research; for no such cooperation can be really effective unless based upon a thorough mutual familiarity with the conditions and an abiding faith in the integrity and sincerity of purpose of each other. It is likely to prove a poor investment for a manufacturer to seek the aid of an investigator if he is unwilling to take such expert into his confidence and to familiarize him with all the local and other factors which enter into the problem from a manufacturing standpoint.

According to the system of industrial research in operation at The Mellon Institute of Industrial Research of the University of Pittsburgh,[2] a manufacturer having a problem requiring solution may become the donor of a fellowship: said manufacturer provides the salary of the fellow selected to conduct the investigation desired, the institute furnishing such facilities as are necessary for the conduct of the work.

The money paid in to found a fellowship is paid over by the institute in salary to the investigator doing the work. In every case, this researcher is most carefully selected for the problem in hand. The institute supplies free laboratory space and the use of all ordinary chemicals and equipment. The fellow who is studying the problem works under the immediate supervision of men who are thoroughly trained and experienced in conducting industrial research.

At the present time, The Mellon Institute, which, while an integral part of the University of Pittsburgh, has its own endowment, is expending over $150,000 annually for salaries and maintenance. A manufacturer secures for a small expenditure—just sufficient to pay the salary of the chemist engaged on the investigation—all the benefits of an organization of this size, and many have availed themselves of the advantages.

Each fellow has the benefit of the institute's very excellent apparatus, chemical and library equipment—facilities which are so essential in modern research; and because of these opportunities and that of being able to pursue post-graduate work for a higher degree, it has been demonstrated that a higher type of research chemist can be obtained by the institute for a certain remuneration than can be generally secured by manufacturers.

There is a scarcity of men gifted with the genius for research, and it requires much experience in selecting suitable men and in training them to the desirable degree of efficiency, after having determined the special qualities required. Important qualifications in industrial researches are keenness, inspiration and confidence; these are often unconsidered by manufacturers, who, in endeavoring to select a research chemist, are likely to regard every chemist as a qualified scientific scout.

All researches conducted at The Mellon Institute are surrounded with the necessary secrecy, and any and all discoveries made by the fellow during the term of his fellowship become the property of the donor.

It is well said in the *Reports* of the Twelfth Census of the United States that

[2] On the progress which has been made in industrial fellowships, see R. F. Bacon, *J. Frankl. Inst.*, November, 1914, 623.

> probably no science has done so much as chemistry in revealing the hidden possibilities of the wastes and by-products in manufactures.
>
> This science has been the most fruitful agent in the conversion of the refuse of manufacturing operations into products of industrial value. . . . Chemistry is the intelligence department of industry.

Yet we are often uninformed concerning the character and amount of the by-products going to waste in our immediate neighborhoods, a careful study of which might lead not only to financial reward for the manufacturer as well as for ourselves, but might also prevent much of the present pollution of our streams and of the air we breathe.

It is not only very desirable, but will soon become really necessary for manufacturers to avail themselves more freely of the assistance of the experts in universities, technical schools and scientific institutes.

THE FUTURE OF RESEARCH IN CANADA

With a strong and prosperous nation to the south, expert in manufacturing operations and constantly endeavoring seriously to gain markets for its surplus production, Canada has developed less rapidly from an industrial viewpoint than if she occupied a more isolated position geographically. European and American products have long been familiar to the Canadian people, and the manufacturers of the Dominion have had an arduous struggle in establishing their wares. But this time is past. Since 1910, all over Canada, new factories have been erected, new products are being manufactured, and new plans for the future are being considered.

With her diversified and abundant mineral resources, her extensive forests and her great power sources, Canada has indeed wonderful industrial prospects. Noteworthily helpful work in the opening-up of various fields has been done by your Department of Mines, whose distinguished division Directors, Dr. Eugene Haanel, of the Mines Branch, and Dr. R. W. Brock, of the Geological Survey, have been pioneers in your industrial development; but as your mineral, wood and water-power wealth become more and more apparent, just so much more will the need for and value of industrial research become apparent to your manufacturers. As in other countries, chemistry will be the pathfinder.

Canada is but at the adolescent period in her industrial life. Your patriotism need not therefore be shocked by apparently

> Nourishing a youth sublime
> With the fairy tales of science.

Many of the natural secrets of your vast country have been gained, laboriously wrought for, but rich rewards await your coming generations who inherit the knowledge gained by an awakened conscience of research.

RAYMOND F. BACON
UNIVERSITY OF PITTSBURGH

OCEANOGRAPHIC CRUISE OF THE U. S. BUREAU OF FISHERIES SCHOONER "GRAMPUS," JULY AND AUGUST, 1914

DURING the past summer the fisheries schooner *Grampus* has continued the oceanographic work of 1912 and 1913,[1] in my charge, with Mr. W. W. Welsh as assistant. The general problem laid out for the *Grampus* cruises of the past three years has been the study of currents, salinities, temperatures and plankton of the coastal waters off our eastern seaboard. In 1912 the work was confined to the Gulf of Maine; in 1913 it extended over the whole

[1] H. B. Bigelow, "Oceanographic Cruises of the U. S. Fisheries Schooner *Grampus*, 1912–13," SCIENCE, N. S., Vol. 38, No. 982, pp. 599–601, October 24, 1913; "Explorations in the Gulf of Maine, July and August, 1912, by the U. S. Fisheries Schooner *Grampus*. Oceanography and Notes on the Plankton," *Bull. M. C. Z.*, Vol. 58, pp. 31–147, 9 pls., 1914.